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Finding objects with segmentation strategy based multi robot exploration in unknown environment

Reza Arezoumand[a,*], Syamsiah Mashohor[b], Mohammad Hamiruce Marhaban[c]

[a]*Intelligent System and Robotics Laboratory, Institute of Advanced Technology, Universiti Putra Malaysia, 43400 Serdang, Selangor, Malaysia*
[b]*Department of Computer & Communication Systems, Faculty of Engineering, Universiti Putra Malaysia, 43400 Serdang, Selangor, Malaysia*
[c] *Department of Electrical and Electronic Engineering, University Putra Malaysia, 43400 Serdang, Selangor, Malaysia*

Abstract

In this paper we address exploration algorithm in flat experimental environment with colored objects for multi robots system. The aim of exploration in unknown environment is finding target points like mine detection in outdoor environment without any positioning device. Two algorithms were investigated in this paper one is frontier based random search algorithm and the second is efficient algorithm based on segmentation strategy. To improve efficiency, each robot had to go to different regions to avoid cumulating robots in one region. Constructed maps for all four regions could be shared and navigation could be done more effectively. For constructing map robot can use on built range finder sensor or using vision based systems. Also the algorithm using segmentation strategy is using frontier base algorithm for exploring divided area. Both algorithm implemented and analyzed in Player/Stage simulation. The result was compared and showed the efficiency of the designed algorithm based segmentation strategy. In simulation this algorithm is tested with different number of robots to achieve better view of efficiency for proposed algorithm in different type of environment like harsh environment as possibility of losing some robots.

Keywords: Multi-robot exploration; Flocking; Exploration ratio; Trajectory prediction

1. Introduction

Robot exploration is a crucial task in the in the area of finding object. Object can be everything. Exploring is very popular term in inaccessible or harsh environment [1-3]. Inaccessible environment described as field like fired or chemical environment [4]. Or normal environment and normal job like cleaning or mapping in usual area [5]. We can use only one robot or using multi robot system to explore area. It is obvious that multi robot exploration is faster [6][7].So in this paper we discuss more about multi robot exploration to provide a snapshot of robots used, as proof of concept. .Another issue that is related to multi robot task is maintain network between them for communication to each other [1][3]. Communication is the key to fulfil a job faster [1].Therefore multi robot systems need to provide a network connection. As they are mobile devices so the connection in that network should be kind of wireless network [8][2][9]. But in this paper we not concern about the networking among them and focus more about the exploration algorithm and trajectory prediction. In the first part of this paper, we reviewed

* Corresponding author. Tel.: +603-89464348; fax: +603-86567127.
E-mail address: gs32862@mutiara.upm.edu.my

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the previous work and in the second part segmentation strategy was discussed. The experimental results come in next part .The last part is conclusion and future work.

2. Related Work

One method that described in [6][7][10][11]is using frontier cell algorithm under wireless network construction. [1] Use one algorithm to avoid deadlock in the task. The another type of exploration that described in [12].It is implemented on the Sensor-based Random Graph search (SRG). In SRG algorithm robots use range finder sensor to discover the unexplored area. Also the robot follow a graph to explorer them. In [2][9], algorithm based on coordinated multi robot was proposed. [13][14][15][16] are based on cost of the robot movement in this algorithm. The nearest robot to goal area is selected. The segmentation technique is also described in [17]. Segmentation algorithm is another way of exploration. In this technique they divide the environment to several segments. In this technique each segment belongs to one robot [17]. The others ways is each robot have duty to explore the proper segment.

Consider an environment that contains some object like wireless sensor. Wireless sensors node have limited range of wireless connection [18]. Wireless sensors should be transferring their data to one host [19]. Transferring action should be done for saving and calculating data. Wireless sensors were deployed randomly without any positioning devices [20]. We need some mobile robot to find wireless sensor and transfer their data to the proper place. So in this scenario one suitable algorithm should be used. For implementing exploring algorithm completely we need wireless network [18][20]. But for this project we want focus on the exploration algorithm and dismiss the networking issue. But in applicable project the wireless network should be constructed among the robot and the host. In this work we presume the wireless network is available through the systems and robots and sensors.

In some previous work the most exploration strategy are based on frontier cell. In [4], the method of segmentation was used. Base of the algorithm in [4] robots are trying to recognize the environment with their range finder sensor. They divide the map in distinct regions. In this paper, an algorithm was described like that but the different in calculating for efficient robot to explore the area. The first step of segmentation algorithm, robots load a map of environment in their memory. After that robots divided area to segments. Position of each segments share with each other. The next step is estimate which region in the map is less explored. For searching object in the less explored segment one robots among them is selected. This choosing strategy based on the nearest robot to aimed segments. This strategy is helpful as probability that the asked object is high in region with less explored ratio. In the first step as system start to work explore ratio of segments is equal and almost zero. So in initial each robot try to randomly choose one segment to start the work .As in first they cannot work based on algorithm. And they have to choose one region randomly. After continuing this manner causing find differentiates between regions explore ratio. So after a while robots can work based on the algorithm. In this system we have two kinds of robots. First kind of robots is exploring robots that have duty to find the object. The second kind of robots is corresponding robot that they gather data from all other robots and give other robots data. Also one corresponding robots can asks for this data. Information from other robots helps to make decision. This manner because robots does not have any head controller to give them the trajectory. So each robot should be followed self-embedded algorithm and they should find the optimal trajectory based on their self only.

3. Segmentation Strategy

3.1. Choosing strategy

For selecting a robot to move in less explored area and find the object is two steps should be followed. First step is selecting the suitable robot based on the kind of object [5]. If one object needs special robot and the object is not founded yet. So the system should guess the object more likely is in special region. This guess based on considering the other region is explored more and the portability of being object in region is high. The interpreting step can be based on this. As being object in high exploration rate is less than other region with less exploration rate. After determining the kind of robot to find the object, robots go to the second step is select the robot among system. By finding and calculating the distance between objects and robots that can do the task we have good factor for

choosing. So find the nearest robot to the region based on position from centre of region is the system suggestion to choose the robot. The centre of region is proposed because the exact position of object not determined and even there is no knowledge of existing of object in the region. If two robots have same condition to do the task choosing process select the robot based on the sequence of their name like robot1, robot2,… that the robot1 selected before robot2.Also the other factor like the remained of their battery charge can be used.

3.2. Dividing strategy

In dividing region in segments first the whole area divide in four segments. Dividing in 4 segments is easiest way of dividing as area is rectangle and we can determine each segments with using X, Y vector. After that when the robot arrives to one of this segment and searches randomly the segment. In the second phase this four segment can divided in smaller segment. If we divide the region in smaller region the other robot can select and search each small segment if they are in idle state. And this procedure may be continuing until the width of segment being smaller that the sensed range by the robot.

3.3. Algorithm description

As described in pervious section this algorithm based on segmentation is using searching technique in frontier based algorithms. But the structure of system is based on multi robot architecture[15][21]. The intelligence in this system is a kind of group decisions the learning achieved by whole system together not only one robot. In this system learning of exploration find in the group decision to choose a region and the appropriate robot to move there. This pseudo-code shows in Algorithm 1. In Algorithm 1 we can see at first the system try to map the environment. This mapping is based on the input data that saved initially on their memory. Next steps one robot is allocated to one region after that. In Algorithm 1 we can see the pseudo-code that every exploring robot most followed in this algorithm. First of all, robots make random exploration to find the object. While if during the wandering any robot can find one corresponding robot they exchange their data. Exploring robots send the information about the area was investigated and the corresponding robot sends data about other robot that encountered before[19].The process of sending data between corresponding robot and exploring robot help all robots to know the explored area.

Algorithm 1 Finding trajectory by one robot

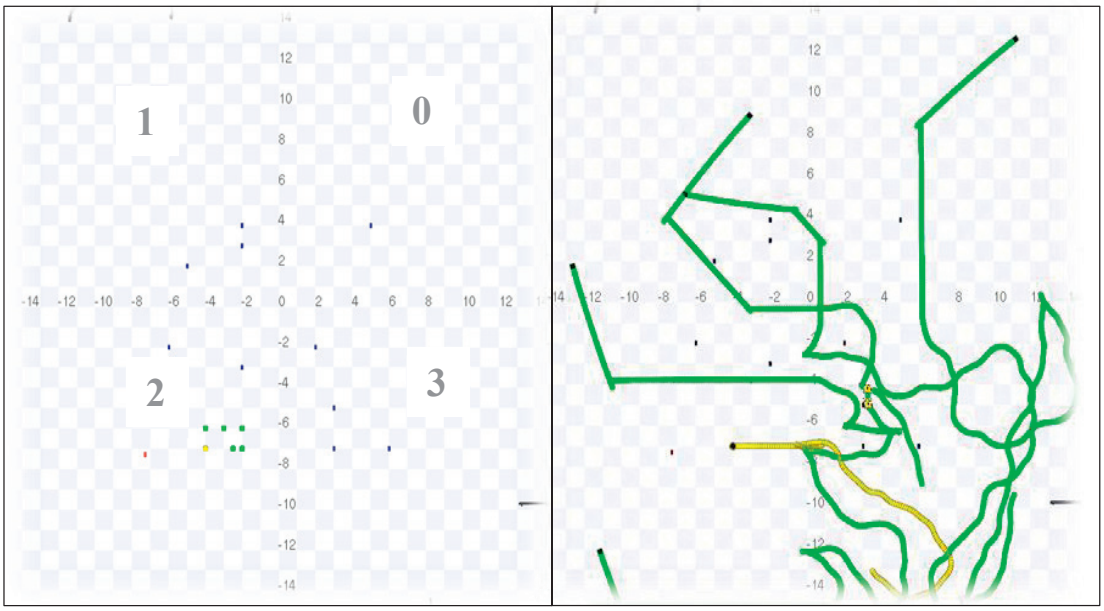
```
// wondering to find object
1-  While 1
2-  //Make random speed and turn speed
3-        i=current region number
4-        Wander(turnspeed, movespeed);
5-  If (encounter corresponding robots) then
6-     Try to receive data
7-     Try to send data region[]
8-     If (receiving data > minimum_ received _data)  then
9-     //calculate the less explored region
10-  Minimum _ explored _region =   Find _minimum _region (received data);//
11-  // Change turn speed and move speed to go in less explored region
12-    Move _robot(turnspeed, movespeed ,  Minimum _ explored _region);
13-  i= Minimum _ explored _region;
14-  End if
15-   Region[i]++;
```

This data also contain the region which they explored. Robots first calculate the amount of data that received to them for considering data which received is enough or not. The term of enough data described as data that more than number of exploring robot minus one, which mean that all robot's data should be received. As determining every robot exploration area then the second phase being started. In the second phase a function named Find _minimum _region try to find the target region. First selection based on segment that explored less than other. Then give segment information to the move_robot function which can control the robot movement to achieve the proposed region. This algorithm continues till all proposed objects are found and the finish condition is proposed.

4. Experiments

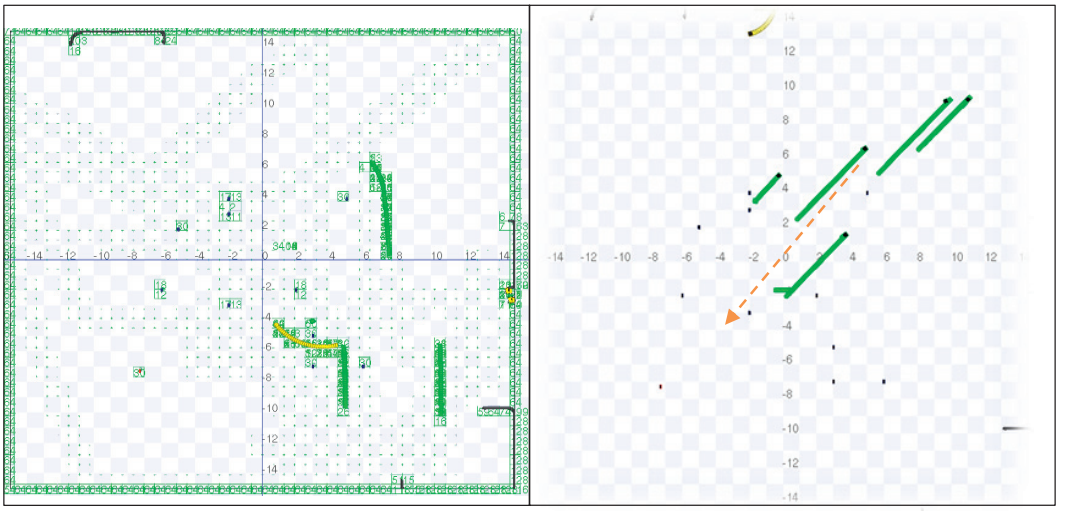
In this part the simulation result is described. Player Stage [22][23] is used in this experiment. Player Stage is a famous software for simulation robots and multi robots system. We construct 5 and 3 exploring robots in two different systems and one corresponding robot. The robots move based two parameter moving speed and turn speed. Forward speed is push robot to forward or backward. Turn speed consider the value turn robot in right or left with adjustable degree of turning. Fig.1a shows the environment of initial stage of robots. Green object is exploring robot and yellow one is corresponding robot. Blue boxes are object that should be found. The number from 0 to 3 in this shape shows the divided region. Each number is one segment considers to its vector for example segment 0 is where both X and Y is positive. In Fig.1b we can see the trajectory of robots in initial exploration based on random exploration [24] in this picture we can see robots mainly flock in small area and in Fig.2a is the occupancy of environment by robots in this Figure some area that marked with plus (+) and the unexplored area is empty .

In second phase after corresponding robots meet all robots and transfer information among them then each robots decide to change direction to the region that has minimum explored area rate. Fig.2b show the changing direction of robots to one region was showed in this scenario. Movement of robots that is showed in Fig.2b.Purpose segment is 1 and all robots change their direction to achieve this segment and the other robots that have been in this region is continue the exploration in this region. The arrow in Fig.2b shows the direction of flocking robots. Robots explore this area with random search algorithm. But if they escape from the aim area they come back to the region by changing direction algorithm like other robots.



(a) (b)

Fig.1. (a) Simulation environment; (b) Initial random searches

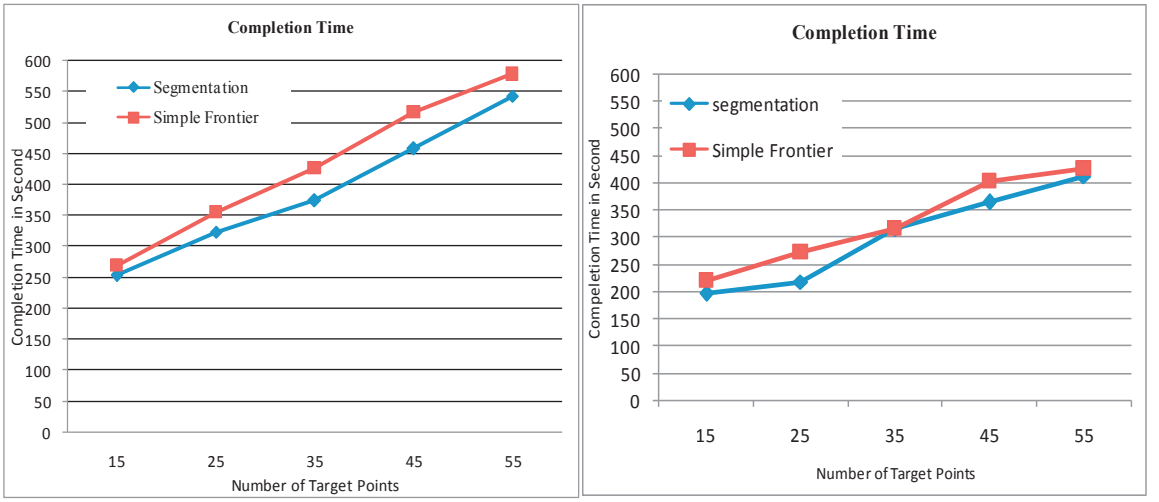


(a) (b)

Fig.2. (a).Occupancy explored environment; (b). Change directions to arrive to minimum explored region

5. Experiment Result

The multi robots system and segmentation algorithm that described in section 6 is used for analysis in this paper. Two multi robot systems were tested with differ in their number of robots team. First system is implemented by using three robots and the second tested system with five robots. The test result comes up with various numbers of targets that they deployed randomly. For comparison we use two types of exploration algorithms. One is proposed algorithm which described in previous section the second is a simple frontier based algorithm [11] that select frontier cell or block region randomly without any concern.



(a) (b)

Fig.3. (a).Exploration time with 3 robots;(b).Exploration time with 5 robots

The simulation runs with 5 different environment that contain of respectively 15, 25,35,45,55 targets object the maximum 55 is due to size of area ($25m^2$) and the sensing range of robot (3m).For more than 55 target point the result not change very much as overlapping to find object by robots.In two charts that showed in Fig.3 we can see the result. This result based on time parameter in two situations which performed fifteen times runs (15 is enough because more that that we have almost same average in concerned parameter). Fig.3.a is the result without segmentation strategy and with segmentation strategy by using three multi robot systems. Fig.3.b is the same experiment like first one but using five robots system. In this charts in Fig.3 the same result is compared with three robots system and five robots system. The average time consuming for fulfil the mission is decreased in both system (three and five robots).Time consumed in 3 robot system with our algorithm decrease 8.9% compare with frontier based algorithm and also in 5 robot system the 9.04% reduced in comparison of frontier based algorithm. Effect in 3 robots system is almost same with 5 robots system. We can see how the segmentation algorithm helps to reduce time and also trajectory movement in the multi robot exploration. The important factor cause segmentation strategy works better than frontier is taking account probability of being object in less explored area so we can see this factor how effect on fulfilling time.

6. Conclusion

One exploration algorithm was implemented and discussed in this paper. This paper shows the method of segmentation in multi robots system. The algorithm was introduced that work based on searching method. The comparison of the analysis part discussed about how robots can to explore an area more efficiently. The result shows the effect of using segmentation strategy in reducing the time of exploration for finding all objects. The other issue we can optimize is energy consumption, because when the time is reduced its mean that robot need less time to be power on and this cause they use less energy. For future work we want change the algorithm for interior dividing of each segment and search them by exploration rate algorithm. Also in this system all robots flock in region with explored less than other regions. In future work we can plan each robot goes to the purpose region based on the how the region is explored before.

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